Accurate Radio Positions with the Tidbinbilla Interferometer

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Originally published in the Proceedings of the Astronomical Society of Australia, *this article discusses the Tidbinbilla interferometer which is designed specifically to provide accurate radio position measurements of compact radio sources in the southern hemisphere with high sensitivity using the 26-m and 64-m antennas of the Deep Space Network at Tidbinbilla, near Canberra. The instrument also provides high-accuracy flux density measurements for compact radio sources.*

Radio position measurements with an error of $< 2''$ arc rms allow reliable optical identifications of compact radio sources to be made solely on the basis of radio-optical position coincidence. In this way neutral or red stellar objects, faint compact galaxies and faint QSOs can be reliably identified. Such identifications are of particular interest because they are rich in BL Lac objects, high-redshift QSOs, QSOs with unusual optical emission or absorption spectra and galaxies with active nuclei (Ref. 1).

The Tidbinbilla interferometer (Ref. 2) is designed specifically to provide accurate radio position measurements of compact radio sources in the southern hemisphere with high sensitivity. The interferometer uses the 26-m and 64-m antennas of the Deep Space Network at Tidbinbilla, near Canberra. The two antennas are separated by 200 m on a north-south baseline. By utilizing the existing antennas and the low-noise travelling-wave masers at 2.29 GHz, it has been possible to produce a high-sensitivity instrument with a minimum of capital expenditure. The north-south baseline ensures that a good range of u-v coverage is obtained, so that sources lying in the declination range $-80^\circ \lesssim \delta \lesssim +30^\circ$ may be observed with nearly orthogonal projected baselines of $\gtrsim 1000\ \lambda$.

For observations of catalogued sources an observing procedure similar to that developed for the RRE Malvern interferometer (Ref. 3) has been adopted. Short observations are made at widely separated hour angles, where each individual observation determines the source position in one dimension. Lobe ambiguities are absent for Parkes catalogue sources, since the positional errors are much less than one lobe spacing. The intersection of these 'cuts' then yields the source position. The sequence of sources is usually selected to be at roughly constant declination and hour angle so that the local antenna coordinates remain roughly constant for those sources.

Normal observations are accumulated for 5 min, yielding an rms noise of 0.9 mJy. In practice the source positional accuracy for weak sources is limited by background confusion rather than system noise. Figure 1 shows the amplitude distribution for 70 high-galactic-latitude random fields; the distribution is sharply peaked around 6 mJy. For a 50 mJy source this corresponds to an rms phase error of $(6 \times 180)/(50\pi\sqrt{2}) = 5°$, or a positional error of $\sim 2''$ arc.

In order to calibrate the instrumental phase and also to determine an accurate baseline, a number of sources with accurate ($< 1''$ arc) radio and optical positions have been observed over a wide range of hour angles. As the two antennas are of differing mounts, the baseline equation has additional terms over that normally employed for identical antennas. At all times the phase drift has been observed to be much less than $2° \, h^{-1}$ and easily followed by observing a calibration source once per hour. Figure 2 shows the observed phase error distribution from observations of a selection of small-diameter sources from the Parkes $\pm 4°$ catalogue (Ref. 4) for which accurate positions have been measured with the RRE Malvern interferometer (Ref. 5). These show an rms phase error of $3°.5$, corresponding to a position error of $\sim 1''.5$ arc. Figure 3 shows a comparison between the Tidbinbilla and Malvern positions: the larger scatter in right ascension results from the two cuts being separated by only 3-1/2 h of hour angle, so that the two cuts were only $30°$ apart on the sky.

By combining the observations from a number of observing sessions it has been possible to refine the baseline parameters to give an rms phase error of $< 4°$ over the available sky at elevations $> 20°$. This corresponds to a positional accuracy in one dimension of typically $2''$ arc. The measured confusion error discussed above shows that an rms positional uncertainty not exceeding $3''$ arc should be achievable for compact sources stronger than 50 mJy at high galactic latitude.

The instrument also provides high-accuracy flux density measurements for compact radio sources. Figure 4 shows a comparison between the measured Tidbinbilla flux densities and interpolated flux densities based on the Parkes 2.7 GHz measurements and measurements at Arecibo at 318 MHz (Ref. 6). Once again the sources were selected to be compact with normal spectra, to exclude likely variables, and chosen from the Parkes $\pm 4°$ catalogue. Dividing the observed scatter equally between the two sets of measurements leads to an intensity proportional error of 1.8%.

Programmes are underway to provide accurate radio positions for southern radio sources. Preliminary results are given in Figure 5, where the radio-optical differences for 11 compact sources selected from the sixth part (declination zone $-30°$ to $-35°$) of the Parkes 2.7 GHz catalogue (Ref. 7) are shown.

Once again the expected right ascension error is larger than the declination error because of the small separation in hour angle of the two cuts. Among the resulting identifications is an X-ray object (PKS 2155-304) which we find to be a radio variable 14th-magnitude BL Lac object: the radio and optical positions differ by less than $1''$ arc in both coordinates.

Acknowledgment

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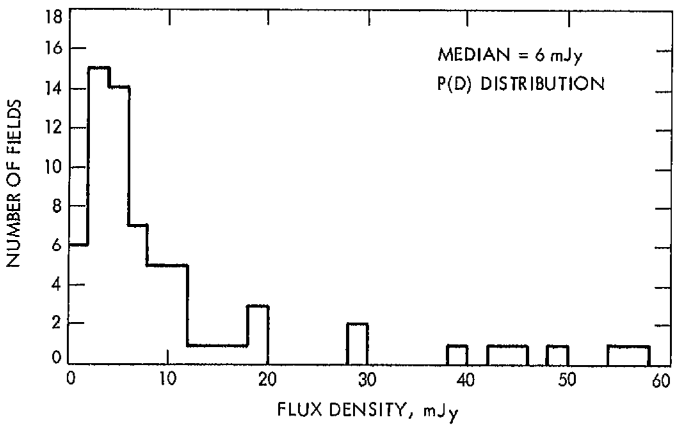

Fig. 1. The amplitude distribution, P(d), for 70 high-galactic-latitude random fields

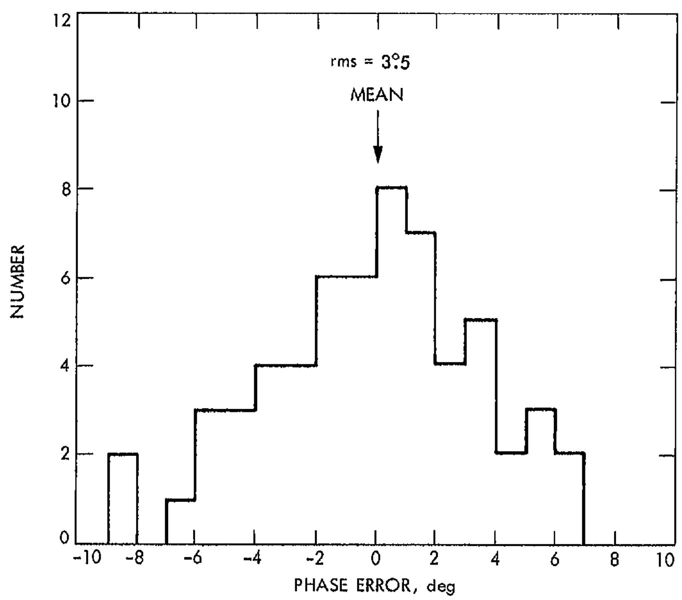

Fig. 2. The observed phase error distribution (TBB-RRE) for 30 small-diameter sources from the Parkes ±4° catalogue

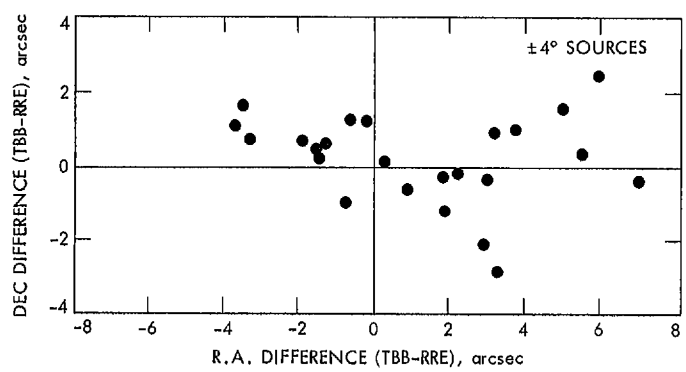

Fig. 3. A comparison between the Tidbinbilla and RRE Malvern position measurements for the ±4° sources

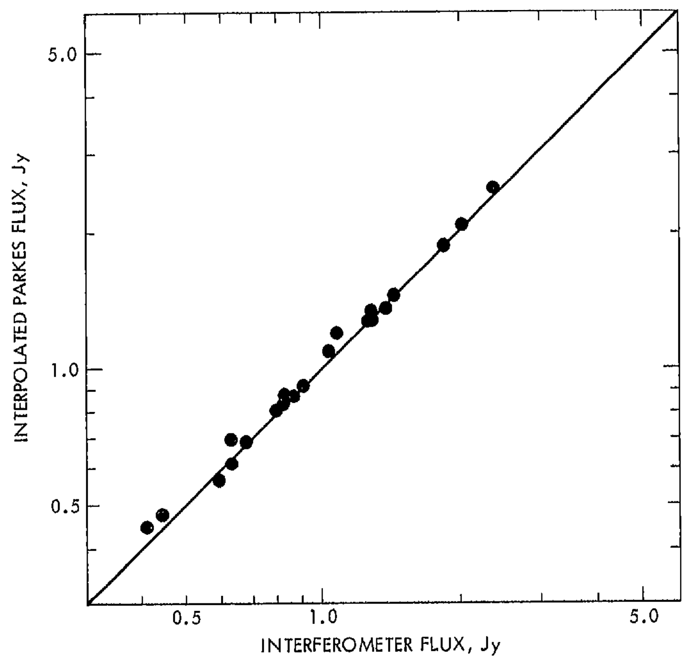

Fig. 4. Flux density comparison between the Tidbinbilla and Parkes measurements for 21 normal-spectrum compact sources from the ±4° catalogue

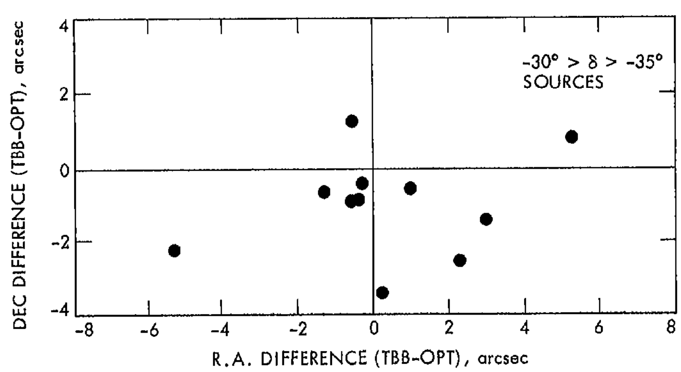

Fig. 5. A comparison between the Tidbinbilla radio and optical positions for the preliminary results from the Parkes −30° to −35° declination catalogue